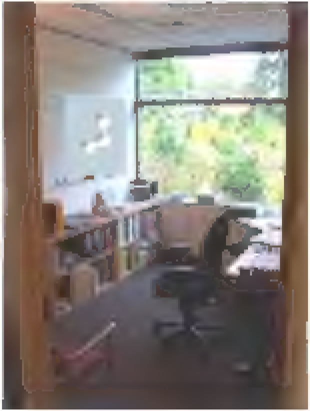
Hardware Devices Research

- Our goal is to provide physical mechanisms to more intimately, naturally, and efficiently connect users with their computing environment.

Tangible Interactive Elements

Desktop



Off-the-desktop

Scope

- Sensors
  - mics, cameras, manual input, trackers
- Emitters
  - optical, acoustic, haptic
- Actuators
  - micro-opto-mechanical systems
- Low power portable or wearable devices
  - and efficient fixed-function processors

Focus

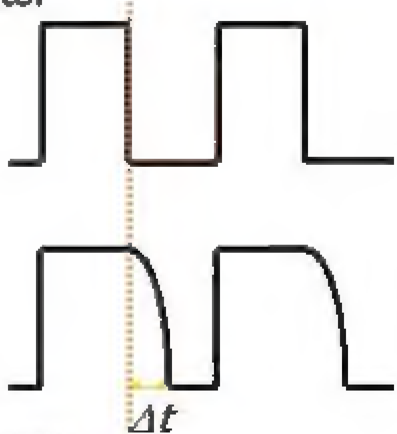
- Touch sensing
  - Mike Sinclair, Ken Hinckley
- Mobile user
  - Turner Whitted, Rob Orr, Victor Bahl
- MEMS
  - Mike Sinclair, Jeremy Levitan
- Flat displays
  - Gary Starkweather, Mike Sinclair, Jim Kajiya

The TouchMouse

- Sense contact from user's hand via capacitance
- New events: *Touch, Release*
  - For Palm area
  - For button, wheel, thumb, ...
  - Enables new interaction techniques.
- Emulation from software doesn't work
  - Did user release mouse? Or just holding still?

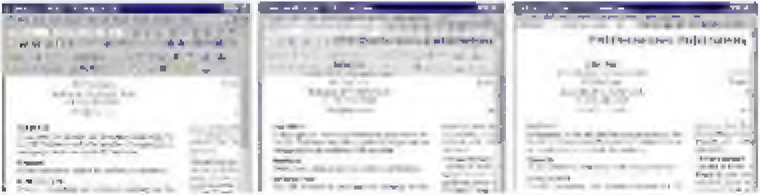
How the TouchMouse Works

- Your body is a capacitor
- Square wave on surface
- Hand causes time delay



What's it Good For?

- Simplify/reduce clutter: Sense user context
  - UI up all the time *vs.* maximum real estate for doc
  - Most widgets only useful when you're holding mouse…
  - So fade in / out portions of display via touch



  - e.g., toolbars are not needed when user lets go of mouse

User Feedback

- Test users loved it: easy and it just does the right thing
  - *"I like that the toolbar comes up quickly when you need it… and all the extra stuff isn't there when you don't need it."*
- No retraining necessary: Just use the mouse the same way you always would

Other Examples of Interaction Techniques

- Enhanced scrolling
  - Tapping for page up / page down
  - Tested very well: paging 4.6 on 5 point scale
  - Doesn't interfere with normal use of wheel.
- Many other possibilities…
  - Touch-to-talk for cueing speech listening mode
  - Auto work: do expensive ops when user is gone
  - Hover detection, cursor sonar, hide cursor
  - *http://msrweb/groups/ui/kenh/home.htm*

Touch-Sensing Input Devices in General

- Many other devices are possible
  - trackball, keyboard, speech headset
  - remote controls, game pads, ...
- Important general properties:
  - *Zero activation force:* implicit sensing of how user is holding device(s)
  - *Flexible form factor:* It's paint. Sense touch on curved surfaces, tight spaces, moving parts, ...
- Exploring use of proximity sensors

TouchTrackball

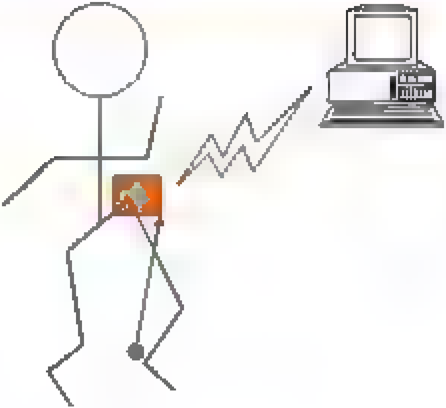
TouchKeyboard

Mobile User

- Sensors and filters for user
  - identity
  - activity
  - intent
- Communications
  - of sensed data
  - voice
  - user "stuff"

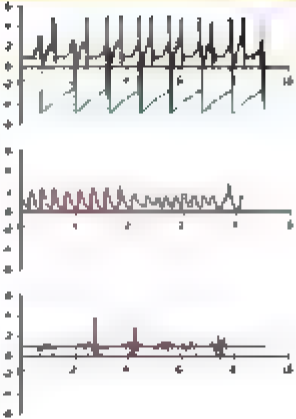
Initial Experiment: Sense, Transmit, Classify

User heel acceleration is measured and forwarded to host for classification.

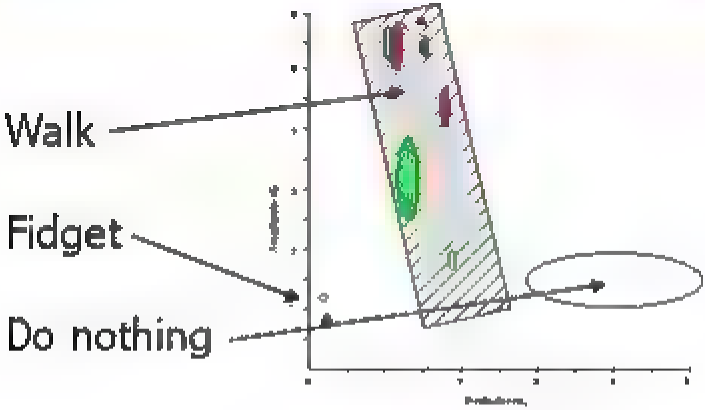


Activity Signatures

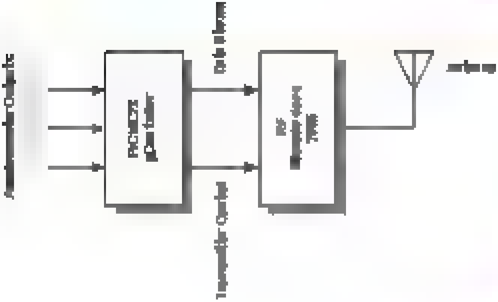
- Several low level/low information sensors may cost orders of magnitude less than a single high level sensor
- Simple signal processing
- Low transmitter duty cycle



Activity Classifier

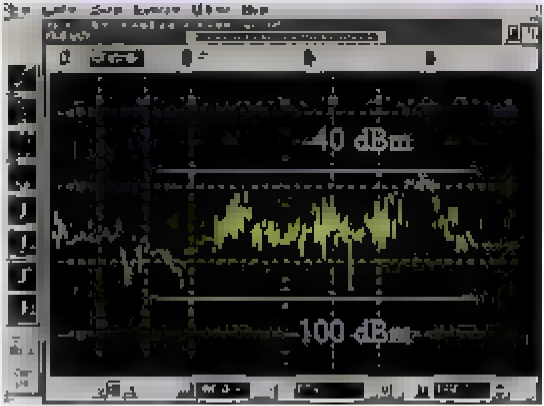


Breadboard Device

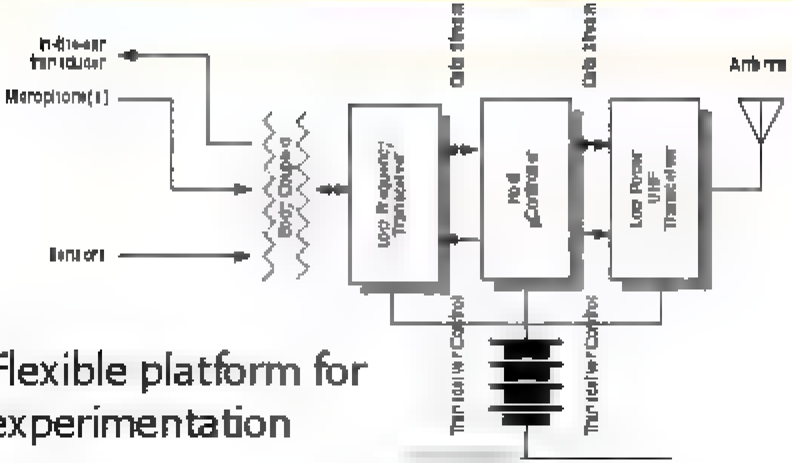


RSSI @900 MHz (in Bldg. 9)

- Transmitter drain:
  - 10 ma @ 3V (full power)
- Signal/dist.
  - ~ $1/r^4$
- Multipath isn't as bad as it looks



BodyCom



Flexible platform for experimentation

Form Factors

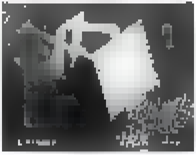
- Non-intrusive
- Minimal

Related Projects

- Elsewhere
  - BodyLan (BBN)
  - PAN (Media Lab, IBM Almaden)
- MCom - wireless PalmPC (MSR)
- Communicator - universal wireless (MSR)
- Chimera (WinCE)

MEMS
(microelectromechanical systems)

- Fairly new technology
- Low barrier to entry
- Low cost - enjoys advantages of existing CMOS fabrication
- Process or auto assembly



- Preferred solution to sensor/actuators
- Popular applications - accelerometers, pressure sensors, digital micro-mirrors

MCNC MUMPS
(Multi-user MEMS Processes)

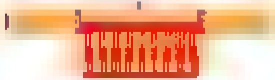
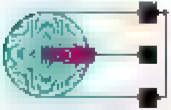
- 7 material layers/
  - isolation
  - conductor (poly)
  - 1st sacrificial (oxide)
  - 1st structural (poly)
  - 2nd sacrificial (oxide)
  - 2nd structural (poly)
  - metal
- We have submitted 3 designs and received 2 chips thus far

MEMS Actuators

- Auto-assembly
  - Single use - requires real estate and external connection(s)

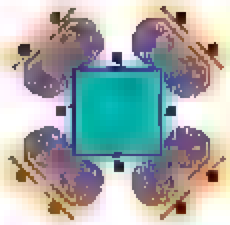
- Continuous use
  - 1D and 2D scanning mirrors, optical cavity length control, grating modulation

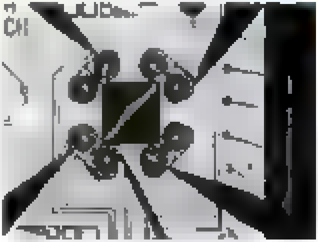
MEMS Actuator Technology

	Energy Density	Real Estate	Elect Power	Voltage	Freq
Electrostatic 	Low	High	Low	High	High
Magnetic 	Medium	Medium	Medium	Low	Medium
Thermal 	High	Low	High	Low	Low

MEMS Actuators - magnetic

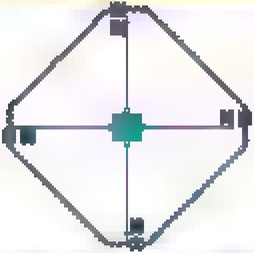
- 2D scanning mirror
  - self elevating, +/- 20 degrees (possible)

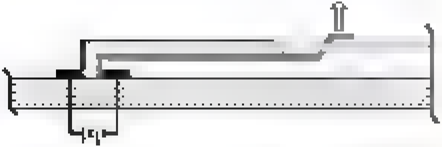




MEMS Actuators - thermal

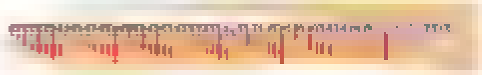
- 2D scanning mirror
  - 200 micron square mirror
  - sliding hinges
  - +/- 7.5 degree measured
  - 490 Hz
  - ~5v @ 9ma max per leg





Scanning mirror - What's it good for?

- 1D linear scanning mirror
  - barcode reader
  - touch planes
  - large screen display with UV phosphors and 1D mirror array



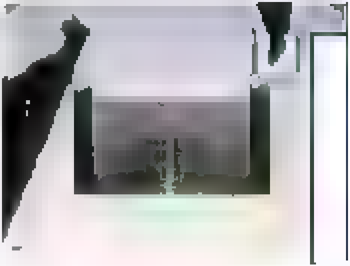
- 2D linear scanning mirror
  - vector display
  - retinal display
  - steerable detector

MEMS Actuators - electrostatic

- Digital linear encoder with comb drive

Programmable Devices

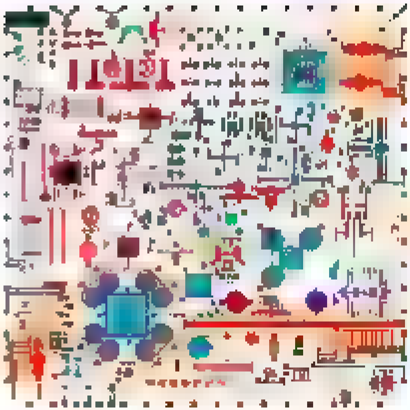
- Fusible links to modify mechanical behavior
  - resonance
  - link placement



- Fuse array
  - reduces external connections
  - predictable

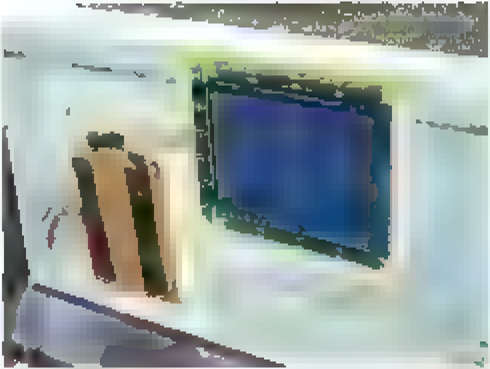
MEMS - future

- MUMPs 28 submission
  - vertical thermal actuators
  - vertical magnetic actuators
  - rotational and linear "inch worm" motors
  - fuse arrays and devices

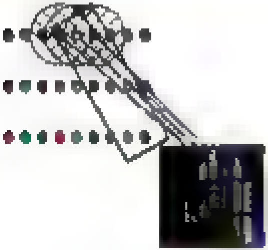


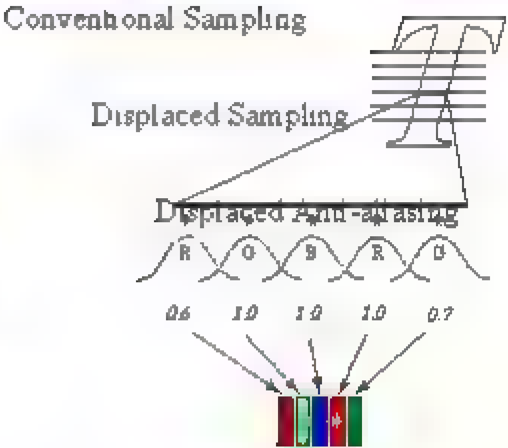
Displays

- LCDs
  - ClearType
- Display quality
- Large format displays



Displaced Sampling



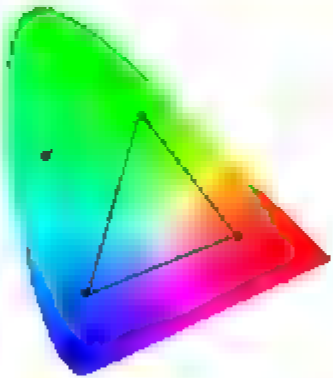


The Future Display Dilemma

- Moral:
  - Full exploitation of display technology follows from the physical characteristics of the display.
- Dilemma:
  - The physical properties of future displays are not known.

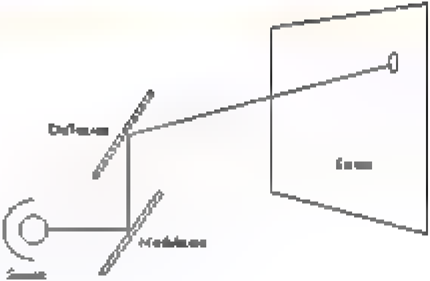
Display Quality: Expanded Gamut (Gary Starkweather)

- Add 4th color to representation
- Expand gamut by 40%



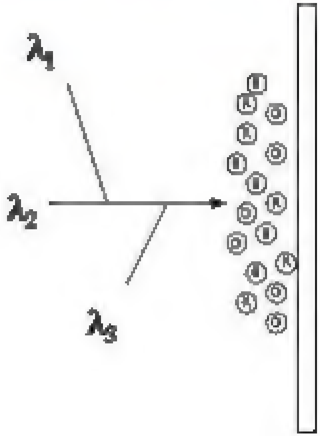
Large Format Display Testbed

- Photo-luminescent
  - no vacuum => light weight
  - MEMS devices for deflection and modulation
- Parallel modulation
  - lower signal bandwidth



Non-patterned Display

- Phosphor slurry: eliminates need for patterning
  - no alignment problems
  - resolution not limited by pattern



Ultra Hi-res Architecture

- Smart wall paper
  - resolution requirements
  - update requirements
  - power requirements

Context

- Smart environments (Easy Living)
- Computers with non-standard form factors (off the desktop)
- Computer mediated communications

[expected] Results

- New I/O => new UI, services
- Lower cost devices
  - even if the whole is greater than the sum of its parts, the parts ought to be cheap
- Abstractions for I/O
  - a driver model that encapsulates the user
  - embedded systems that work well